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Development of a GIS for Sea Surface and Sea Bed Phenomena for Hazard Prediction in Hydrocarbon Drilling Environments

by

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Hazards associated with marine, hydrocarbon drilling including sea ice, iceberg, meteorological and sea surface information, are usually stored on separate databases or maps. GIS provide the capability of integrating, scaling and manipulating spatially distributed data, overcoming the limitations of traditional media. Sea surface temperature images from satellites can be combined with salinity, sea ice thickness, wave regime and other environmental data to develop a model of ice deterioration by correlating overlays of spatial data. Similarly, iceberg scour depth can be integrated with surficial geology and bathymetry to examine the spatial relationships between scour depth, bathymetry and seabed sediments. Strategies required to develop a GIS that will enable scientists to examine multivariate spatial relationships between marine phenomena (e.g. water body and sea bottom data recorded on Canada's eastern continental shelf areas -- the Grand Banks, Labrador Shelf) are presented. To demonstrate the methodology and data structure required to develop such a GIS, a spatial model for iceberg scouring on Canada's eastern continental shelf is developed. This modelling process synthesizes iceberg information, sea ice coverage data, wave and current regimes, iceberg scour data, surficial geology and distinct, but complementary, environmental data. A prototype of this unique, non land-based GIS is presented.

1.0 INTRODUCTION

Research on icebergs has increased tremendously since the beginning of oil exploration programs off Canada's east coast. This increase in iceberg research is directly related to the hazard posed by icebergs drifting into areas where offshore oil wells are being drilled. The hazards presented by icebergs are twofold: (a) there is the potential for a direct collision with an offshore structure; and (b) grounding and scouring icebergs could crush and plough subsea installations such as wellheads, mooring systems and pipelines. Iceberg scours are formed when an iceberg keel interacts with the seabed (Figure 1). Scours observed by sidescan sonar on the continental shelf areas are grouped into two classes (a) relatively long furrows and (b) circular to elliptical pits (Figure 2).

The purpose of this study is to develop a spatial model for iceberg scouring on the Canadian eastern continental shelf area. The SPANS geographical information system (GIS) will be used to develop the model and present the results of the analysis. The intent of this research is to provide the necessary tools to permit the analyses of spatial relationships between iceberg scours and pits. It will provide the type of oceanographic, geological, iceberg and sea ice data needed to gain a comprehensive understanding between the distribution and physical dimensions of iceberg scours and environmental data. This paper presents an overview of the project.

1.1 PROBLEM

The identification of surface and sub-surface hazards associated with marine hydrocarbon drilling and development programs are usually treated as separate entities. For example, sea ice, iceberg, meteorological, and sea surface information would usually be stored on separate databases or maps. This information could only be integrated by time consuming tasks such as redrawing a map or reformatting data within a rigid database structure. The former task is labour intensive and time consuming while the latter task may be nearly impossible. The data structure used in a particular database may not have the flexibility to merge data from many different sources and so efficient spatial analysis and modelling will not be possible.

A majority of the data collected for offshore areas contain a spatial component (i.e. latitude and longitude); traditional databases, however, do not permit analysis of spatial relationships that exist between the various data sets. Traditional presentation media (i.e. maps) represent static information with which data from only a limited number of sources (e.g. numerical data and maps) can be combined coherently. Therefore, indepth manipulation of comprehensive data for modelling a oceanic or subsea process (e.g. sea ice/iceberg deterioration or iceberg scouring) is very difficult to perform.

1.2 A SOLUTION

Geographical information systems (GIS) have the ability to integrate, scale and manipulate spatially distributed data from many different sources. For example, sea surface temperature derived from satellites can be combined with salinity, sea ice thickness, wave regime and other environmental data from a variety of sources. This combined information may then be used to develop a model of ice deterioration by correlating the factors upon which the process depends. GIS may also be used to create overlays of spatial data and multi-variable maps that can be updated by adding new variables or data. For example, iceberg scour depth can be overlaid with surficial geology and bathymetry to examine the spatial relationships between scour depth, bathymetry and seabed sediments.

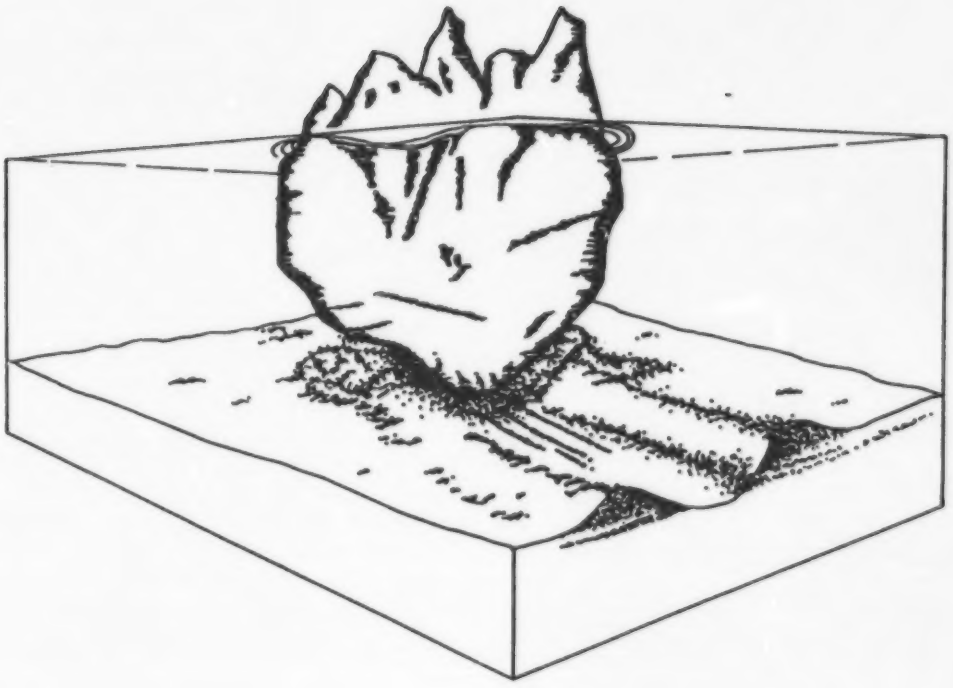

Figure 1: A conceptual drawing of a scouring iceberg.

(Source: C.M.T. Woodworth-Lynas, 1984.
C-CORE News, Vol. 9, No. 1)

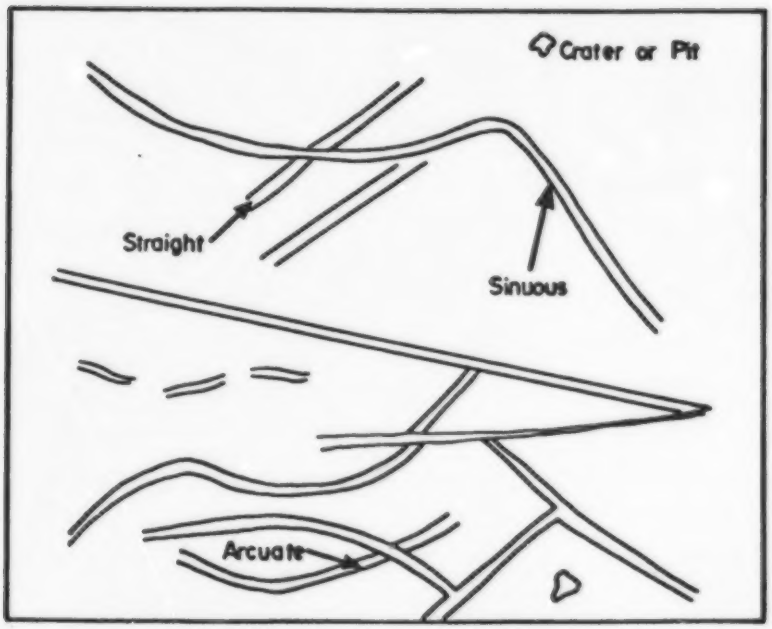

Figure 2: Examples of straight, arcuate and sinuous iceberg furrows and an iceberg pit.

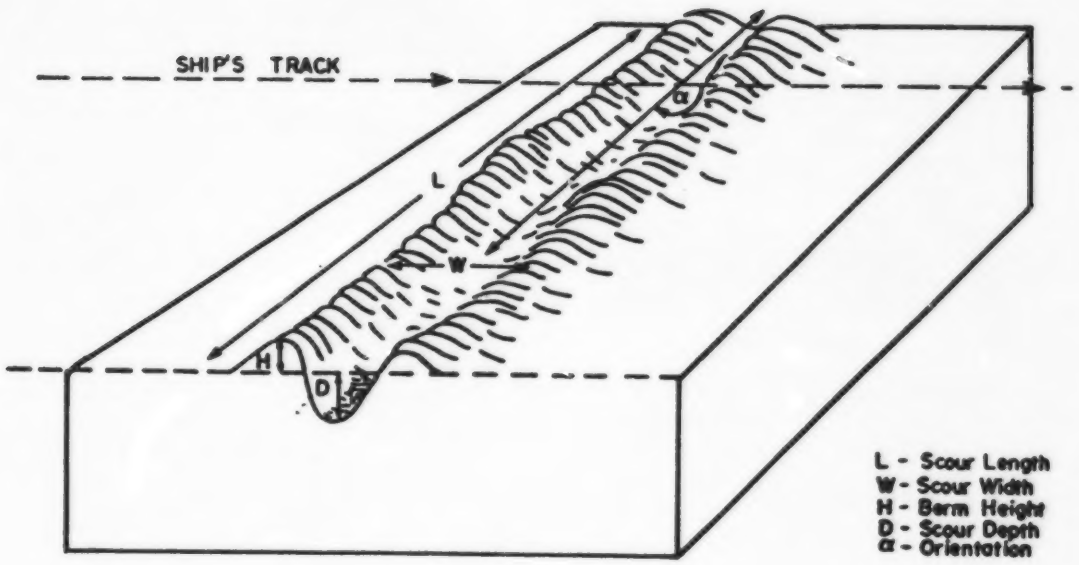

Figure 3: Representation of the measured dimensions of an iceberg furrow.

2.0 BACKGROUND

Since 1972 iceberg scour data, covering an area from the Grand Banks to Baffin Bay, have been collected by oil companies, the Atlantic Geosciences Centre (AGC) at the Bedford Institute of Oceanography (BIO), and the Centre for Cold Ocean Resources Engineering (C-CORE). These data are archived on the "East Coast Iceberg Scour Database" [d'Apollonia and Young 1987]. The data set contains information on the physical dimensions (Figure 3) and characteristics (such as scour width, length etc.) of iceberg scours and pits.

The database will be augmented by including digitized data from sidescan sonar mosaics compiled by C-CORE and other agencies which are presently excluded from the scour database. Data from other sources, such as maps and numerical information on iceberg drift patterns, documented iceberg grounding and/or scouring events, sea ice distribution, surficial geology and oceanography (i.e. bathymetry) will be also added. For example, a majority of the preceding information is being digitized from existing published maps (i.e. bathymetric charts) and from 1:2 M to 1:250,000 M compilations for Decade of North American Geology and Frontier Geoscience Program, currently in press. Finally, the iceberg and sea ice information is archived on the Canadian Sea Ice Information System (CSIIS) at C-CORE. Additional iceberg and sea ice information will be collected from Atmospheric Environmental Services (AES) and International Ice Patrol (IIP).

2.1 GIS AND APPLICATIONS IN ICEBERG SCOUR MODELLING

A geographical information system (GIS) is a "computer system for collecting, storing, retrieving, transforming, analysing, measuring, recombining and modelling spatial data from the real world for a particular set of purposes" [Burrough 1986]. Just as statistical relationships can be deduced between numerical data sets, similar relationships can be determined between spatial data sets. GIS's are the result of linking parallel developments since 1940. These are, automated data capture, data analysis and presentation in the broadly related fields of topographical mapping, thematic cartography, civil engineering, geography, mathematical studies of spatial variation, soil science and image analysis [Smith, *et al.* 1987].

One of the objectives of GIS is to ensure that data from many sources can be integrated. For example, integrating the east coast scour database (point and line data with multiple attributes) with information on seabed surficial geology (polygonal, thematic data at different scales), oceanographic data (point data), iceberg/sea ice information (point and polygon data) and remotely sensed data would provide a consistent information base that can be used for exploring the spatial relationships between iceberg scours and associated environmental/geological data. These relationships are important because specific combinations of seabed sediments (i.e. sand) and associated environmental conditions may result in scour infilling. This may give the impression that some areas are more prone to scouring than others. An examination of the spatial relationships may reveal that the area is scoured quite frequently (Figure 4).

GIS's can serve as modelling tools for iceberg scouring and will make it feasible to examine a range of possible scenarios that will provide an understanding of the spatial relationships between iceberg scours/pits, surficial geology, oceanographic parameters, iceberg drift patterns and sea ice distribution.

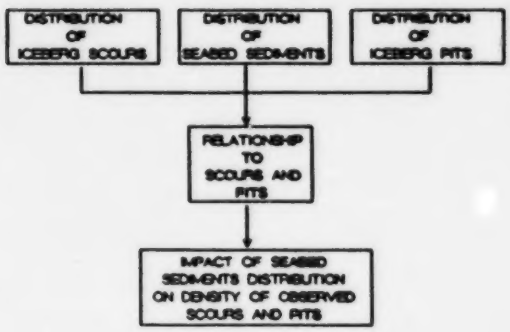
DISTRIBUTION OF ICEBERG SCOURS
DISTRIBUTION OF SEABED SEDIMENTS
DISTRIBUTION OF ICEBERG PITS
RELATIONSHIP TO SCOURS AND PITS
IMPACT OF SEABED SEDIMENTS DISTRIBUTION ON DENSITY OF OBSERVED SCOURS AND PITS

Figure 4. Model Flowchart.

Furthermore, a GIS-based modelling approach will enable the analysis of scour data from various geographical areas (i.e Grand Banks and Labrador Shelf) whereby it would be possible to determine differences and similarities in the scouring processes between the regions.

3.0 METHODOLOGY

The project focuses on the development of an iceberg scour model through the SPANS geographical information system. Several benefits associated with the development of an iceberg scour model are: (a) it will be able to identify areas where the potential for the collision of iceberg keels with subsea installations (e.g. subsea wellheads, anchoring/mooring systems and power cables) will be minimal, (b) the GIS - based approach will provide a dynamic research tool with which new parameters (e.g. geotechnical data on seabed soil properties) and scenarios for scouring processes can be added to the model at any time.

The system hardware and software configurations are presented in Figure 5 and 6 respectively. The system is configured to complete all the tasks required to develop an iceberg scour model using a GIS-based approach. These tasks fall within the following categories:

(a) data encoding and input processing (digitizing/frame grabber),

(b) data management/retrieval (relational DBMS/SQL),

(c) data manipulation and analysis (SQL, spatial statistics, multivariate statistics,gridding/contouring and SPANS),

(d) data display and presentation (SPANS) [Burrough 1986 and Smith *et al.* 1987].

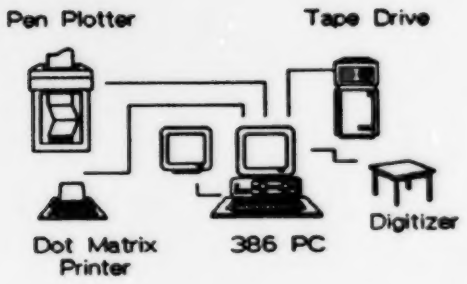

Figure 5. GIS Workstation

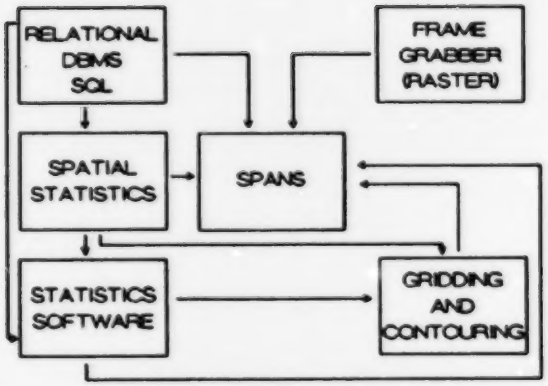

Figure 6. Software Components.

Data input requirements for the project will include the integration of data from the east coast scour database, geological maps, oceanographic parameters (numeric and map data), iceberg movement data (including known grounding and scouring information) and sea ice distribution data. Distributions associated with theoretical grounding and scouring models will also be encoded in the data set. These data will require both manual and automated preprocessing prior to encoding. The preprocessing will involve: (a) format conversion - this refers to standardizing the data structure or different data media (i.e. converting map information, such as bathymetry and surficial geology, to a digital format), (b) error detection and editing [Smith, *et al.* 1987].

After the different data formats are standardized the data will be stored on a micro computer DBMS. This process will facilitate the orderly retrieval of the data for analysis. The DBMS will be an industry standard system (e.g. DBase, INGRES, ORACLE etc.). The first two tasks ensure data consistency and efficient data storage and retrieval. However, the final tasks consist of the development of the scour model on the geographical information system and the presentation of results. The data manipulation and spatial analysis task includes procedures such as polygon overlay and cell overlay (i.e. spatial correlation functions). The overlays created during the modelling process (e.g. distribution of scour depth, length or width) will be stored as overlays on the GIS system from which they will be accessible for any future analysis.

4.0 CONCLUSION

SPANS is the core of the system (Figure 6); however, the relational DBMS is used to store all point information. Line and polygon information is stored with the SPANS data structure. The spatial statistics, statistics software and gridding/contouring software permit additional data manipulation. For example, small scale noise inherent in some point data can be removed by spatial filtering techniques, e.g. spatial moving average.

The project will provide insight into:

(a) the methodology for iceberg scour modelling through GIS,

(b) an empirical iceberg scour model describing correlations between significant environmental parameters and icebergs scour type

(c) a manipulation strategy for the assessment of the spatial variation in iceberg scours and pits,

(d) risk assessment maps for potential offshore oil production areas on the Grand Banks

(e) iceberg feature classification (e.g. crater chains, long scours,non-linear scours etc.)

(f) an enhanced database with information on iceberg scours, geology and oceanography for areas located on the eastern Canadian continental shelf.

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